Quantum topology and deep learning

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1 Project goal

This project aims to apply the newest developments in computer science to mathematical physics. More precisely, I would like to use algorithms that are able to learn from the big sets of data very effectively (which is the essence of deep learning) to tackle unsolved problems in quantum topology. This young field of research uses models from quantum physics to describe topology – a part of mathematics that views all objects as if they are made of rubber (this allows for stretching and shrinking, but not gluing or tearing apart). From topological perspective, a table and a plate are the same, however different than a mug, which is like a donut.

One of the most important branches of quantum topology is focused on properties of knots, which most of the people know from shoelaces, sailing, and irritating tangled wires. In recent years, together with my collaborators, we proposed a totally new approach to knots. We used quivers, which are graphs made of nodes and arrows between them. The main goal of the project is transforming quivers into a universal language of description of knots by the use of deep learning.

2 Description of research

In the first part of the project the research in knots and quivers as well as studying applications of deep learning in mathematical physics will go in parallel. This will allow for bringing these fields and their languages closer together in a stepwise fashion. After this preparations both lines of research will connect and deep learning will be applied directly to quiver description of knots.

At all stages of the project I will collaborate with researchers from the team that will be created during the project, as well as scientists from universities and institutes around the world. This will include University of Warsaw, Jagiellonian University, University of Wrocław, Ludwig-Maximilian University of Munich, University of Amsterdam, Academia Sinica in Taipei, University of Tokyo, and California Institute of Technology (Caltech).

3 Reasons for attempting this research topic and substantial results expected

Since computers can process graphs very effectively and deep learning enabled algorithms to recognise images and speech, translate languages and play chess extremely well, I would like to use this power to discover new relations and structures, perform advanced computations, and find guidelines for proving mathematical theorems.

In the future, better understanding of knots could be applied in the studies of the DNA and proteins structure, which are potentially useful in producing antibiotics and anti-cancer drugs. Another important application is the area of quantum computing, which may lift computers to another level and revolutionise our technology.

Moreover, if deep learning will turn out to be effecive in quantum topology, it will encourage more mathematicians and physicists to use it more often. It will bring even more exiciting discoveries that change our understanding of the world and, in the long term, allow for more applications that improve our quality of life.